Extended abstract

The Kerguelen plateau phytoplankton bloom: from local to regional and seasonal to interannual scales

by

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In contrast to the high-nutrient low-chlorophyll (HNLC) conditions observed throughout most of the Southern Ocean, the waters over the deep (0-1000 m) Kerguelen Plateau in the Indian Ocean sector exhibit an annual phytoplankton bloom (up to ~3 mg Chl *a* L^{-1}). The KEOPS field study (KErguelen Ocean and Plateau compared *Study)* (Blain *et al*., 2007) in late summer (Jan.-Feb. 2005) found ~3-fold stronger vertical gradients in dissolved iron concentrations over the plateau, and estimated that this was close to sufficient to fuel the enhanced production during the observed period of bloom decline.

Comparison of the satellite-derived surface chlorophyll *a* (SCHL) to bathymetry and altimetry-based currents reveals complex structure and unexpected results (Mongin *et al*., 2008). Flow at the Polar Front where it crosses the Plateau just south of Kerguelen Island is associated with persistently low SCHL waters that separate the central plateau bloom studied by KEOPS from the influence of Kerguelen Island. The biomass variations do not show simple correlations with water depth on the central plateau, and the highest biomass is often found over 300-500 m troughs which appear to experience higher velocity currents. Biomass develops strongly in November, peaks in concentration and expands over and off the plateau in December and January, and then declines and retreats in size in late January and early February.

For a three-fold increase in sub-surface iron concentration (Blain *et al*., 2007), the 1-D biogeochemical model (Mongin *et al*., 2008) reproduces the off-plateau and on-plateau seasonal SCHL cycles, and extending it to a 2-D grid using a satellite altimetry-based eddy diffusivity, allows it to roughly capture the size of the bloom and its expansion off the plateau (though it is clear that advective circulation, not included in the model, controls many aspects of the SCHL distribution). The 1-D model exhibits similar carbon, nitrogen and silicon concentrations to the KEOPS observations, but differs dramatically in terms of estimated seasonal iron budgets. This arises for several reasons: i) the model's mixed-layer variability parameterization leads to higher iron supply than that estimated from the observed iron gradients and vertical diffusivities, ii) the model assumes a higher winter surface iron concentration than was estimated from subsurface remnant winter water values during KEOPS, and iii) the model allows strong variability in the Fe:nutrient uptake stoichiometry and this leads to efficient iron uptake even at low biomass levels. That uptake further fuels dissolved iron supply to the mixed layer, and is accompanied by a high Fe:nutrient export ratio (in part because of the lack of an iron microbial loop in the model). This strong cycling of iron leads to very low carbon sequestration efficiency estimates.

The mechanisms bringing on the bloom shape were strongly influenced by the bathymetry and by the strong currents around the plateau; but those justifications alone are not sufficient to explain the bloom pattern. Maraldi *et al*. (2009) focused on lateral mixing to find explanations of the bloom particular shape. They compute the Smogarinsky formula (Smogarinsky, 1963) to estimate lateral mixing time scales τ due to barotropic tidal currents, barotropic atmospheric forced currents, Ekman and geostrophic velocities. Results show that short time scale mixing is strongly influenced by the tidal process while the other processes have minor influences on it. Comparisons of τ and satellite chlorophyll images show that the characteristic pattern of the bloom seems to be delineated by a barrier of high lateral mixing essentially due to tides.

Summer-time studies have demonstrated that iron from the islands and intervening shallow plateau (300-600 m) fuels localized production. Whether this supply, or alternatively iron brought to the surface by enhanced mixing of the Antarctic Circumpolar Current (ACC) eddies, drives the more extensive downstream bloom, has not been addressed. Mongin *et al*. (2009) showed that the extent and shape of the downstream bloom can be reproduced by simulating the winter-time spread of a slowly-decaying tracer (iron) from the islands and plateau using a satellite-altimetry based advection scheme. This suggests that mesoscale activity in the ACC plays a minor role in generating the enhanced biomass and emphasizes the importance of shallow bathymetry, large-scale advection, and winter-time observations in understanding the productivity of the Southern Ocean.

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